Catena 133 (2015) 198–205

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Effect of tea plantation age on the distribution of soil organic carbon fractions within water-stable aggregates in the hilly region of Western Sichuan, China

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ARTICLE INFO

Article history:
Received 12 August 2014
Received in revised form 16 May 2015
Accepted 20 May 2015
Available online 27 May 2015

Keywords:
Tea plantation age
Soil aggregate
Soil organic carbon
Labile organic carbon fractions

ABSTRACT

Establishment of tea plantations (*Camellia sinensis* L.) could markedly change the pools of soil organic carbon (SOC) and labile organic carbon (LOC). However, the effects of different chronosequence phases on the quantity and quality of SOC in such plantations were poorly understood. In this study, we investigated SOC dynamics following farmland conversion to tea plantations of 16-, 23-, 31-, and >50 years old in Zhongfeng Township of Mingshan County, Sichuan, which is in southwest China. We specifically examined the effects of the age of various tea plantations on the concentrations of SOC and LOC, including readily oxidizable carbon (ROC), water soluble organic carbon (WSOC), microbial biomass carbon (MBC), particulate organic carbon (POC), and mineralizable organic carbon (MOC) within soil water-stable aggregates. We found that the contents of very coarse fraction (>5 mm) and very fine fraction (<0.25 mm) dominated in the soil of the different tea plantations. Importantly, contents of water-stable aggregates at the size of >5 mm and mean weight diameter (MWD) in 23 year old tea plantation were seen to be higher when compared with >50 years, indicating that maximum soil stability was within soil macro-aggregates. SOC, ROC, POC, MBC, and MOC contents were reduced with the decreasing of particle size except for WSOC. On the whole, the SOC concentrations in >50 yr. of tea plantations at two soil depths were significantly lower than those of 23 yr. In addition to WSOC, other LOC contents changed in trends parallel to SOC, demonstrating that tea plantation reaching up to about 23 years contributed more to the soil quality than >50 yr.

1. Introduction

Soil aggregates are considered to be a sort of carrier in stabilizing and protecting soil organic carbon (SOC). Most studies have been conducted to evaluate the effects of soil aggregates on the decomposition and transformation of SOC and soil fertility (Arai et al., 2013). In addition, water stable aggregates (WSAs) are an important index in evaluating soil physical properties and anti-erosion capabilities, as their abundance in the soil is closely related to SOC concentration (Šimanský et al., 2008). WSAs are mainly composed by the cementing of soil inorganic and organic substances, and can improve the nutrient recycling and enhance water availability (Carter, 2002; Whalen et al., 2003). Therefore, an understanding of SOC pools in WSA is important in assessing carbon and nutrient dynamics in agricultural ecosystems.

Within the context of WSA and their vital role, various fractions of SOC with different physical and chemical properties are stabilized by specific mechanisms, thus resulting in different levels of soil stability and turnover rates. For example, SOC shows the balance of mineralization and decomposition, but it cannot accurately reflect the changes in soil due to land cover change. However, labile organic carbon (LOC) fractions are thought to be sensitive to changes in soil land use (Eynard et al., 2005; Qi et al., 2012; Wu et al., 2003). Therefore, LOC can be considered as indicators of changes in soil quality and sensitivity to environmental factors compared with SOC (Wang et al., 2012; Xu et al., 2006). Although the separation techniques are different in readily oxidizable organic carbon (ROC), particulate organic carbon (POC), microbial biomass carbon (MBC), water-soluble organic carbon (WSOC), and mineralized organic carbon (MOC), they all indicate the LOC. Based on the different essential characteristics of SOC fractions, measuring some smaller or more active indicators of SOC fractions, is a significant method for characterizing changes to SOC quality caused by land use change.

Most studies on SOC dynamics within aggregate fractions concentrate on agricultural and forest ecosystems but little attention focuses on tea plantations (*Camellia sinensis* L.) (An et al., 2010; Bandyopadhyay et al., 2010; Chen et al., 2012; Jagadamma and Lal, 2010). As a perennial evergreen crop, tea plantations gradually form a unique regional ecosystem due to their root absorption characteristics, root exudates, and typical tea plantation management (Kamau et al., 2008). Some studies have shown that soil properties will change with the increasing of tea

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http://dx.doi.org/10.1016/j.catena.2015.05.017
0341-8162/

plantation age and affect the composition of soil aggregates and the distribution of aggregate-associated carbon (Wang et al., 2013; Xue et al., 2007). However, the effects on SOC and LOC fraction distribution within WSA in the hilly region of Western Sichuan, China undergoing farmland conversions to tea plantations have not been studied in detail, and its ecological effect is increasingly in the spotlight. Thus, characterizations of SOC dynamics within different aggregate fractions during this change in land use pattern need to be understood.

The objectives of this study are twofold. First, to assess and quantify the short and long-term effects of farmland conversions to tea plantations on the distribution of WSA; and second, to determine the distribution of SOC and LOC fractions within different WSA fractions of tea plantation soils according to a range of plantation ages. This will provide a soil-focused theoretical basis for effectively converting farmland to tea plantations and the sustainable development of such tea plantations.

2. Materials and methods

2.1. Study area

The study area is an ecological tea plantation in the Zhongfeng town of Mingshan county of Ya'an city (103°11′42″–103°12′02″E, 30°12′04″–30°12′43″N) (Fig. 1). This region is typical of the hilly areas of Sichuan (mean altitude 700 m) and has a subtropical monsoon climate (mean annual temperature 15.4 °C; mean annual rainfall of above 1500 mm with 72.6% of precipitation between July and September). The exposed layer is sedimentary rocks mainly formed after the Mesozoic age, and the soil type is Luvisols formed in the older alluvium. Original vegetation was comprised mainly of subtropical evergreen broadleaf plants. But the majority of forests were gradually transformed into farmland as the population increased. Since the 1990s, a pattern of converting farmland to tea plantation has been implemented in the Upper Yangtze River Basin. Sichuan tea plantations of varying ages were the dominant cultivar in the study area.

Tea cultivation and fertilization are shown below: tea planting density is 150 cm ± 15 cm when trees are spaced in large intervals, while 35 cm ± 15 cm is typical of smaller spacing. Pig manure (15,000 kg hm^{-2}) and K_2SO_4 type fertilizer (N: P_2O_5: K_2O = 20:8:8) as the base fertilizer are spread along vertical edges beneath the tree canopy in mid-October, followed by adding complex chemical fertilizer, pig manure, and finally, mulch covering. A top dressing of the tea plantations is added 3 times per year. The following year in mid-February, 1500 kg hm^{-2} of complex fertilizer and urea 600 kg hm^{-2} are applied; in late May and July, complex fertilizer 750 kg hm^{-2} and urea 300 kg hm^{-2} are added to the soil, the position of the top dressing is the same as the basal dressing.

2.2. Experimental design and soil sampling

We chose four Sichuan tea plantations with different ages, including 16 years old (16 yr.), 23 yr., 31 yr., and >50 yr., which were located on similar characteristics such as soil type, soil parent material, slope directions and fertilizer addition regime. The distance between the four tea plantation sites was about 35 m. Each site had five plots, which with the total area sampled, measured 15 m × 15 m (225 m^2), and the distance between the five plots was 15 m. Then, five sampling points were made by S-shaped sampling method in each plot. After that, soil samples were collected from the depths of 0–20 cm and 20–40 cm below the edge of the tea canopy. Two hundred soil samples were randomly collected from all of the plots with the aid of a spade to maintain the soils in their natural aggregates. Soil samples were sealed in plastic boxes and transported to the laboratory. One part was passed through a 5 mm screen for the measurement of WSA. Another part was stored at 4 °C to avoid any influence of preparation on microbial biomass

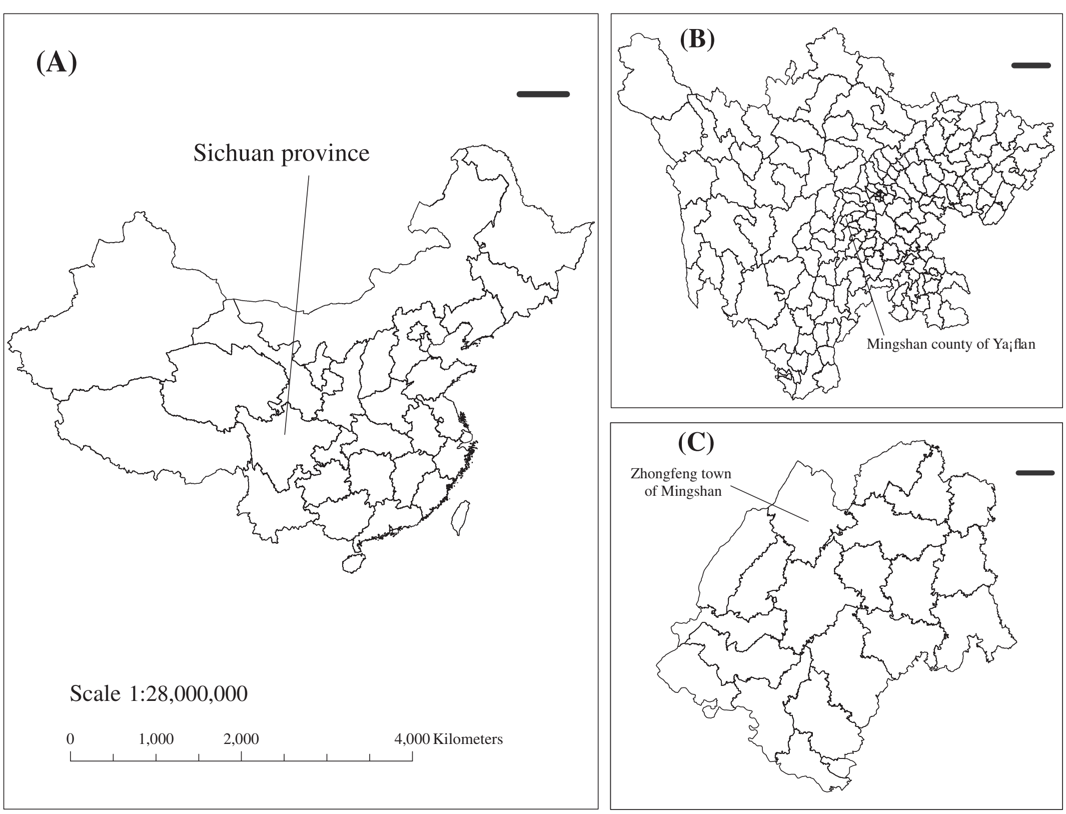

Fig. 1. Location of the study area.